June 15, 1920

PRICE 25 CENTS

AVIATION
AND
AERONAUTICAL ENGINEERING

Thomas-Morse S4E Single-Seater Scout

VOLUME VIII
Number 10

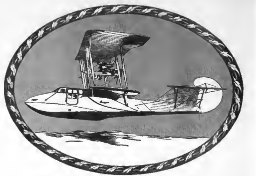
Three Dollars a Year

SPECIAL FEATURES

DETERMINATION OF SWEEPBACK FOR LINE-UP
TWO NEW CLARK AEROFOILS
PROPELLER THEORY AND DESIGN
OVER-CLOUD FLYING AND COMMERCIAL AERONAUTICS

PUBLISHED SEMI-MONTHLY
BY
THE GARDNER, MOFFAT CO., INC.
HIGHLAND, N. Y.
HARTFORD BUILDING, UNION SQUARE
22 EAST SEVENTEENTH STREET, NEW YORK
Entered as Second-Class Matter, May 19, 1920, at the Post Office at Highland, N. Y., under Act of March 3, 1879.

"The Motor That Made the Spad Possible"
These Advantages Helped Make a Better Airplane Engine for You
THE Wright-Hispano Aeronautical Engine is the American development of the famous French motor which was designed in 1914 to incorporate advantages not possessed by other engines at that time.
Further American development has brought about many important changes in the original design which has "carried on" still further the competitive advantages that have always been so characteristic of this great engine.
It is our purpose to make clear to the plane builder and owner in these pages the advantages possessed by the Wright-Hispano Engine in dependability, compactness, streamline, flexibility, accessibility, weight-to-horse power and reliability.
In no other way can this Organization so well acknowledge its obligation to the manufacturer and the flyer and its firm purpose to remain pre-eminent in the aircraft motor field.
There are available for immediate delivery 180 H P (Model E) Engines to recognized plane manufacturers and responsible owners.
WRIGHT
Aeronautical Corporation
New Brunswick N.J.
Member Manufacturers' Aircraft Association
Lewis & Vought
V-E-7
powered with
Wright-Hispano
Aeronautical Engine
WRIGHT-HISPANO



AVIATION AND AERONAUTICAL ENGINEERING

JUNE 15, 1920 VOL. VIII NO. 10

Member of the Audit Bureau of Circulations

INDEX TO CONTENTS

THE GARDNER, MOFFAT COMPANY, Inc., *Publishers*
HIGHLAND, N. Y.
HARTFORD BUILDING, UNION SQUARE, 22 EAST SEVENTEENTH STREET, NEW YORK

SUBSCRIPTION PRICE THREE DOLLARS PER YEAR. SINGLE COPIES TWENTY FIVE CENTS. CANADA, THREE AND A HALF DOLLARS. FOREIGN FOUR DOLLARS A YEAR.

ISSUED ON THE FIRST AND FIFTEENTH OF EACH MONTH. FORMS CLOSE FIVE DAYS PREVIOUSLY. ENTERED AS SECOND-CLASS MATTER MAY 18, 1920, AT THE POST OFFICE AT HIGHLAND, N. Y., UNDER ACT OF MARCH 3, 1897

Thomas-Morse Training 2-Seater in flight over Ithaca, N. Y.

L. D. GARDNER, PRESIDENT AND EDITOR
W. D. MOFFAT, VICE PRESIDENT
W. I. SEAMAN, TREASURER
H. M. WILLIAMS, GENERAL MANAGER

AVIATION AND AERONAUTICAL ENGINEERING

ALEXANDER KLEMIN, TECHNICAL EDITOR
LADISLAS D'ORCY, ASSOCIATE EDITOR
GEORGE NEWBOLD, BUSINESS MANAGER

Vol. VIII June 15, 1920 No. 10

In a recent copy of *L'Aeronautique* a French author explains in a very logical fashion the manner in which internal combustion engines may be adapted for altitude flight.

In the early stages of the war everything was done to improve the power of a motor by the increase of compression, by the increase of piston velocity and by the use of special materials to secure lightness. A motor was sought which should give greater power at the ground, thereby, giving greater speed and climb, but the general improvement in the motor did not necessarily mean that there would be a corresponding improvement at altitude. On the contrary, there would still be the same proportionate loss at altitude. As the importance of altitude flight came more and more to the fore, means of improvement solely from an altitude point of view came under consideration. On this line of thought, compression at the ground was increased beyond the point of safety, were the motor to be used at its full possible power at the ground. A dangerously compressed motor at ground level would at altitude be a perfectly practical mechanism. At the same time, attempts were made to lighten the motor beyond the point which would be justified by the very high compression on the hypothesis that the motor would be only used at its full power at altitude and would therefore not meet the great stresses which the high ground compression involves.

These methods of slight variation in design proved only moderately satisfactory. The idea of the turbo-compressor was attacked simultaneously in different quarters. It may be said that the turbo-compressor has successfully passed the experimental stage, but the difficulties in its installation and use are very great.

It is far from being in production and it is yet doubtful how soon it will be a commercial possibility.

A number of writers, besides M. Villey, have suggested other methods. One of these is to vary the compression by a suitable lengthening and shortening of the connecting rod. Another method is to increase the cylinder volume in flight. These methods offer thermo-dynamic possibilities. The mechanical difficulties are large but are not such as to be beyond solution. It would seem that this line of attack would offer certain possibilities to engine designers.

Ground Speed Indicators

Though many efforts have been made in developing a ground speed indicator, they have so far proven fruitless. Some of the experiments have been on the lines of ground sighting instruments, necessitating a complicated system of surveying from the air. In other cases, attempts have been made to integrate accelerations by a system of complicated mechanism. While much ingenuity has been spent on this work, both principles were faulty because they involved of necessity undue complication.

Mr. Hersey, of the Bureau of Standards, now states a principle which has not yet been fully applied, but seems free from insuperable difficulties in execution. A working model consists of a large steel ball free to roll back and forth in a glass tube, filled with a viscous fluid. Simple mathematical considerations will show that if the fluid resistance is directly proportional to the speed of the ball through the tube in a horizontal fore and aft position, then the displacement of the ball at any instant from its initial position in the tube is directly proportional to the absolute ground speed of the aircraft.

This indeed is a beautiful conception. The only practical difficulty remaining to be overcome is a provision of a suitable gyro-stabilizer to hold the tube horizontally. This certainly is not impossible of achievement. We can therefore look forward with hope to the development of an absolute ground speed indicator.

Variation in Lift Coefficients with Speed

In a paper on the Physical Basis of Air-Propeller Design F. W. Caldwell and E. N. Fales describe a high speed tunnel running as high as 400 m.p.h., in which some peculiar phenomena on the value of life coefficient were observed. As a rule, it has been assumed that while the drag coefficient of a wing diminished with the products of scale and velocity, the coefficient of lift remains practically unchanged.

The experiments mentioned indicate that there is indeed an asymptotic value for the lift coefficient but that there is a great change from a low value of LV to a high value of LV. This is another shock to the aerodynamicist who seeks to co-relate his wing tunnel data with his full flight tests.

Production of Instruments in Quantity

In no country is the problem of securing quantity production so well understood as in the United States. But, on the other hand, in European industries, it is found that workmen will work with greater artistic feeling and will achieve better results than ours would, in working without rigid standards or specifications. As a result, in the production of delicate instruments during the war, French and British manufacturers were able to achieve quantity production long before the instruments had passed the experimental stage, while in the United States this was practically impossible.

These remarks apply to many other line of engineering work. Sooner or later, it is to be hoped that industrial education will provide us with a type of man who is as much of an artist in his work, as the French and British mechanic.

Cleaning Rags in Fuselage

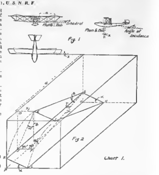
A German writer states that cases have occurred where cleaning rags have been left in the fuselage by the ground personnel.

These rags subsequently got into the control wires, and jammed the rudder, with disastrous results. Here is a cause of trouble which, in case of an accident, might be unjustly attributed to the designer.

A skilled ground personnel in commercial aviation will be only second in importance to careful and skillful design and careful piloting.

Determination of Sweepback for Line-Up

By T. P. Wright
Lieut. (j. g.), U. S. N. R. F.



It is evident that if a dihedral angle is given to a panel having a built-in angle of incidence, a certain back sweep of the wing will result. As a great many biplanes and triplanes are now being built having a horizontal upper panel, with a lower panel having a dihedral angle, it is necessary to determine the amount of this sweepback in order to properly line up the machine. The line up of the upper and lower panels, relative to each other, is usually performed by dropping a plumb bob from the leading edge of the upper panel and measuring the distance therefrom to the leading edge of the lower panel. This distance, the stagger, (usually tested in lining up machines at each strut point) will increase from wing root to wing tip in machines built as above stated.

The formula, with deduction of same, to be used in determining the increase in stagger from wing root to wing tip is given below. References are to the accompanying chart.

Let $GHLK$ be a panel having angle of incidence α. Revolve this plane upward to position $GHEI$, so that $EGF = \theta$, the dihedral angle. Let a be the distance from wing root to desired strut point, along a line which is parallel to and in a vertical plane passed through the leading edge of the upper panel (considered in this case as having no dihedral angle). Let DJ be a plumb line at the desired strut point, a distance from the wing root, and x the required unknown distance.

ΔKLP is similar to ΔJEF (Three sides perpendicular)

$\therefore \angle KLP = \angle JEF = \angle \alpha$ (Angle of incidence)

$x = b \tan \alpha$

and $b = c \tan \theta$

$\therefore x = c \tan \theta \tan \alpha$

but $c = a \cos \gamma$

$$\therefore x = \frac{a \tan \theta \tan \alpha}{\sin \gamma} \qquad (1)$$

also $x = a \tan \gamma \qquad (2)$

$$\text{Let } (1) = (2) \qquad \frac{a \tan \theta \tan \alpha}{\cos \gamma} = a \tan \gamma$$

$\therefore \tan \theta \tan \alpha = \tan \gamma \cos \gamma$

but $\tan \gamma \cos \gamma = \sin \gamma$

$\therefore \sin \gamma = \tan \theta \tan \alpha$

$\therefore \gamma = \sin^{-1} (\tan \theta \tan \alpha)$

from (2), $x = a \tan \times \sin^{-1} (\tan \theta \tan \alpha) \qquad (3)$

As the first variation in sin and tan in a 4 place table occurs at 3 deg., or .0523, no variation in the results secured by application of (3) would occur by dropping the tan and sin term, until an angle of incidence *and* dihedral of 13 deg were reached. Therefore, for all practical purposes, formula (3) may be written $x = a \tan \theta \tan \alpha$

The application of this formula to three Navy seaplanes is given below.

MODEL NC

a (wing root to outer strut) = 29 ft. 4⅛ in. = 352⅛ in.
α = 3 deg. (angle of incidence)
θ = 3 deg. (dihedral angle)
$\therefore a \tan \alpha \tan \theta$ = .965 in., or approximately 31/32 in.
(This result checks with that found at time of set up)

MODEL MF

a (wing root to outer strut) = 11 ft. 11 in. = 143 in.
α = 6 deg. (angle of incidence)
θ = 2 deg. (dihedral angle)
$\therefore a \tan \alpha \tan \theta$ = .525 in. or approximately 17/32 in.
(This result checks with that found at time of set up.)

MODEL HS-2

a (hinge point to outer strut) = 13½ ft. = 162 in.
α = 4 deg.
θ = 2 deg.
$\therefore a \tan \alpha \tan \theta$ = .396 in. or approximately 13/32 in.

It is evident from the above examples that this feature should be taken into account in lining up all machines on which this condition exists. Failure to do so will result in a line up which imparts an unnecessary initial strain in the wing structure by forcing the panel forward.

Two New Clark Aerofoils

Some very interesting wing sections have recently been developed by Maj. V. E. Clark, of the Engineering Division, United States Air Service. Two of these section, called the U. S. A. 26 and the U. S. A. 27, are moderately thick and are therefore suitable for small internally braced airplanes, or for wing trusses having longer bays than usual. This feature alone would constitute a sufficient advantage to recommend the use of these aerofoils in many cases, but in addition their aerodynamic characteristics show a great improvement over other sections which allow the use of even moderately deep beams.

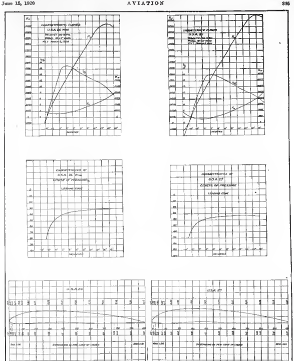
The U. S. A. 26 is the thinner of the two aerofoils and has a higher maximum L/D while the U. S. A. 27 has a considerably higher maximum K_y and a better speed range. As regards climb, the two aerofoils are practically equivalent, with a slightly advantageous showing for the U. S. A. 26.

On the whole, however, the U. S. A. 27 is the better of the two sections and it is believed to be the best all round wing developed to date. The following tabulated comparison will bring this fact out very clearly, all tests being made under the same conditions.

Aerodynamic Characteristics of U. S. A. 26 and U. S. A. 27

Aerofoil	Max. K_y	Max L/D	L/D At 2/3 max. K_y	L/D At 1/4 max K_y	L/D At 1/8 max K_y
U. S. A. 26	.00310	17.0	14.6	12.3	7.9
U. S. A. 27	.00359	16.2	13.7	12.0	7.7
U. S. A. 5	.00328	16.2	14.6	11.4	6.3
R. A. F. 6	.00303	16.8	13.8	10.1	7.5

The development of these wing sections by Major Clark marks a most important advance in aerodynamics and will have considerable influence in improving the performance of airplanes.



Characteristics of the U. S. A. 26 and the U. S. A. 27 Aerofoils

Notes on Propeller Theory and Design

By Alexander Klemin

Consulting Engineer, Aerial Mail Service; Consulting Aeronautical Engineer

The Propeller as a Windmill or Brake in the Airplane

The propeller acts as a windmill, when rotation and an effective torque are produced by the action of the air flowing past it, as contrasted with the propeller or tractor in which the forced rotation produces an effective thrust.

While windmills are frequently used on airplanes to drive gasoline pumps or wireless generators, the propeller of every day use has, under certain conditions, a definite action as a windmill.

Its action under such conditions is of decided interest to aeronautical engineers. Thus —

1. A propeller may act as a windmill on a glide, in which case it may reduce the terminal velocity of a vertical glide and vitiate the results of a measurement of airplane resistance

2. It may develop considerable braking effect on the landing run, and help to shorten the landing run.

3. It may develop braking effect when one engine of a twin-engine machine is shut off, and thus render manoeuverability and sustention harder than is generally taken to be the case.

4. It may act as a windmill on a steep glide, and the engine may be re-started in this way, without the aid of a starter

Elementary Theory of the Propeller Acting as a Windmill

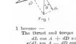


Fig 1

When the propeller is acting as a windmill the translational velocity must be large enough relative to the rotational velocity, so that the angle of incidence is negative and the lift negative as shown in Fig 1

The thrust and torque on an element as shown in Fig. 1 become —

The thrust and torque on an element as shown in Fig 1

$dL \cos A + dD \sin A$

$r(dL \sin A - dD \cos A)$

and the efficiency of the windmill element becomes —

$$\frac{2\pi rn\,(dL \sin A - dD \cos A)}{V\,(dL \cos A + dD \sin A)}$$

Since the efficiency is now the work done by the torque divided by the work exerted by the thrust of the air, putting $\frac{dD}{dL} = \tan B$ and $\frac{2\pi rn}{V} = \cot A$ and dividing numerator and denominator by $dL \cos A$, this becomes

$$\text{Cot } A\ \frac{\tan A - \tan B}{1 + \tan B \tan A} = \text{Cot } A \tan (A\text{-}B) = \frac{\tan (A\text{-}B)}{\tan A}$$

Aerofoil Momentum Theory for the Windmill

This may be developed for the windmill in similar fashion as for the propeller acting as a tractor

Neglecting race rotation, the effect on the stream will be to diminish its velocity relative to the windmill, since it must receive a negative acceleration

Suppose velocity, when stream impinges on the propeller, to be $V - v_1$ and after passing the propeller when again in a region where the pressure is equal to the static pressure of the stream elsewhere, suppose velocity to be $V - v_1 - v_2$

Then $dT = dM\,(v_1 + v_2)$ and $dT\,(V - v_1) = \frac{1}{2} dM \left[(V)^2 - (V - v_1 - v_2)^2 \right] (v_1 + v_2)\ \ (V - v_1) = \frac{1}{2} \left[V^2 - (V - v_1 - v_2)^2 \right]$

From which it follows that $v_1 = v_2$ for this case also, similar to the condition for the propeller.

Still neglecting race rotation the diagram of forces on the blade element becomes:—

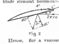


Fig 2

For a perfect fluid the efficiency would be $\frac{V - v_1}{V}$ in which case all the work done by the fluid is converted into work of torque.

Hence, for a viscous fluid, the complete expression for efficiency becomes $\left(\frac{V - v_1}{V}\right) 2 \times \frac{\tan (A - B)}{\tan A}$

Discussion of Wind Mill and Brake Action of Elements of the Blade

The readiest way of forming a conception of windmill and brake action of the propeller is to consider a blade element on a propeller, the characteristics of the element being known at all angles of incidence. For this reason the blade element may be taken as having the characteristics of the R. A. F. 6—a British report gives values of K_y, K_x and L/D for this at all angles of incidence.

TABLE I

Angle of incidence	K_y in lb./sq.ft./sec. units	K_x in lb./sq. ft. /sec. units	L/D
—90°	—.0000585	.001485	—0.05
—80°	—.0003040	.001445	—0.21
—70°	—.0005000	.001415	—0.35
—60°	—.0006470	.001175	—0.55
—50°	—.0007550	.000968	—0.78
—40°	—.0008750	.000810	—1.08
—30°	—.0007530	.000578	—1.35
—20°	—.0006300	.000280	—1.08
—15°	—.0005830	.000235	—2.44
—10°	—.0005200	.000154	—3.38
—5°	—.0002640	.000073	—3.60
—0°	+.0002140	.000036	+5.88

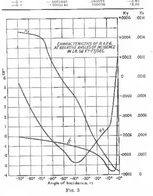


Fig. 3

In Table I are given the coefficients for those angles which are employed in our calculations. These are plotted in Fig. 3

Assume the blade element to be at a radius of 4 ft., set at a pitch angle of 15 deg., and consider a constant translational velocity of 100 ft./sec., or 68.5 m.p.h., this value being taken to give a concrete illustration. The usual relationship then follows —

$$A = \tan^{-1} \frac{V}{\pi nd} = \tan^{-1} \frac{V}{2\pi rn}$$

$$i = C - A \qquad B = \tan^{-1} L/D$$

$$T = L \cos A + D \sin A =$$

$$K_y \times \frac{V^2}{\sin^2 A} \times \cos A + K_x \frac{V^2}{\sin^2 A} \times \sin A =$$

$$\frac{V^2}{\sin^2 A} (K_y \cos A + K_x \sin A)$$

$$Q = r\,(L \sin A - D \cos A)$$

$$= r \frac{V^2}{\sin^2 A} (K_y \sin A - K_x \cos A)$$

$$e = \cot A \tan (A - B) = \frac{\tan (A - B)}{\tan A}$$

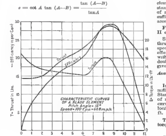


Fig 4

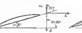


Fig 5.

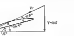


Fig 6.

In Table II are tabulated the results of some calculations for the constant forward speed of 100 ft./sec. and varying values of n and V/nd which are plotted in curves of Fig. 4.

We shall consider some typical cases.

(a) $n = 0$ propeller at rest $V/nD = \infty$

In this condition, the relative velocity is at a large negative angle to the blade. While the drag coefficient is large, the lift does not increase the thrust, and since there is no rotational velocity, the resultant velocity is small. Hence while the negative torque effect is quite large, the thrust is considerably smaller than at lesser values of V/nd

(b) $n = 8$ with $V/nd = 1.56$

While in this condition, the lift coefficient is not at its greatest value, and the drift coefficient is quite small, the resultant velocity is high, and both thrust and torque components are at their maximum values. The windmill efficiency also is high

Other cases might be studied in similar fashion, but the table and the curves indicate quite clearly that the blade element will develop its greatest braking effect, not at a standstill but at a stage where there is an appreciable speed of rotation. If with the propeller at a standstill there is sufficient torque to turn the engine over at all, it will soon accelerate to the point of maximum braking effect.

From the windmill equation and the calculations of Table II certain other deductions are also possible.

Since $i = C - A$, C should be small to give a large negative thrust since i will then be large at appreciable rotational speeds when $\cos A$ should also be large and A small. The efficiency for the propeller acting as a windmill also improves with the L/D of the section when used at negative angles. A double cambered section would assist in this, since it would give both high negative lift values and a high efficiency

Available Wind Tunnel Results on Propeller Acting as a Windmill or a Brake

Information on the action of a propeller acting as a windmill or as a brake is available from the N. P. L. and Leland Stanford laboratories. It seems useful to present the results of all such laboratories in the same manner, and in plotting curves to use the ratio V/nd as the abscissa, where V = velocity of advance in ft./sec., n = r.p.s. and d = diameter in ft.

The best method of presenting coefficients for thrust and torque is the non-dimensional one, as usually employed.

$$\text{Thrust coefficient} = T_c = \frac{T}{\Delta/g\ D^2 V^2}$$

TABLE II $V = 100$ ft./sec., $r = 4$ ft.

n r.p.s.	$\frac{V}{nD} = \frac{12.5}{nD}$	$\tan A = \frac{V}{\pi nD}$	A	$\sin A$	$\cos A$	$i = C - A = 15° - A$	K_y in lb. sq.ft./sec.	K_x in lb sq.ft sec	$\frac{V^2}{\sin^2 A}$	Thrust in lb $T = \frac{V^2}{\sin^2 A}(K_y \cos A + K_x \sin A)$	Torque in ft. lb $Q = \frac{rV^2}{\sin^2 A}(K_y \sin A - K_x \sin A)$	$e = \frac{2\pi n}{VT} Q$
0			90°	1	0	—75°	.000425	.00144	10,000	14.4	17.0	0
2	6.25	1.99	63.3°	.893	.442	—48.3°	.000775	.000948	12,870	14.37	16.2	.118
4	3.12	.995	44.8°	.705	.712	—29.8°	.000704	.000871	20,170	16.44	12.9	.186
6	2.08	.642	33.5°	.553	.834	—18.5°	.000623	.000304	32,800	22.7	12.6	.252
8	1.55	.497	26.4°	.445	.896	—11.4°	.000560	.000178	50,500	28.2	16.0	.285
10	1.25	.398	21.7°	.370	.930	— 6.7°	.000351	.000101	73,000	26.8	10.5	.245
12	1.04	.331	18.3°	.314	.949	— 3.3°	.000166	.000534	111,300	18.4	1.67	.042

$$\text{Torque coefficient} = Q_c = \frac{Q}{\Delta/g\ D^3\ V^2}$$

in any consistent system of units. In this note, as in other notes of the series, T is in lb., Q in ft. lb., V in ft./sec., d in ft., Δ density in lb. per cu. ft., g in ft./sec.² units.

For static tests, that is where there is no translational velocity,

$$\text{coefficients are}\quad T_c = \frac{T}{\Delta/g\ n^2 D^4}$$

$$\text{and}\quad Q_c = \frac{Q}{\Delta/g\ n^2 D^5}$$

The standard density employed—which will be used throughout these notes on propellers—is that of air at 760 mm. pressure and 16 deg. C., which is 0.079 lb./cu. ft. The value of g is 32.2 ft./sec.²

Propeller-Windmill Tests at the N. P. L.

In Fig. 7 is illustrated a four-bladed 2 ft. diameter propeller used at the N. P. L. in these tests. The blades are seen to be

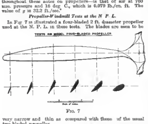


FIG. 7

very narrow and thin as compared with those of the usual two-bladed propeller.

The propeller was tested on the whirling arm in the usual way at translational speeds of 1800, 2200 and 2600 ft. per min. The value of the experimental mean pitch or the advance per revolution when the propeller is giving no thrust was found to be 2.04 ft. The results of tests are given in Table III and in curves of Figs. 8 and 9. The curves in Fig. 8 faired in well from the tests at these three translational speeds showing that departures from "squared law" are small for this range. Table III also gives the thrust and torque coefficients when the propeller is revolved in air at rest.

There is a pronounced maximum point for the windmill efficiency occurring at a small value of V/nD.

It is interesting to note that the values of negative thrust and torque are not at their maximum value when the revolutions are zero. This is in accord with our investigations of the forces on a single element of a blade. When the propeller is not rotating, the K_x coefficient for an element may be very large, but the resultant velocity is smaller than in the case where it is the resultant of both translational and rotational velocity.

Propeller-Windmill Tests at Leland Stanford

Dr. W. F. Durand has tested in the Leland Stanford Laboratories a whole series of propellers for negative thrust. Reference is appended to his report, but a very useful idea of the braking action of a propeller may be obtained by a consideration of the results of some of these.

In Table IV are given the characteristics of the propellers, 1, 2, 5, 6, 9, 10, and in Figs. 10 and 11 the two forms of blades and the sections as they appear in form F_1 with smaller blade width. The pitch was uniform for these two blades. The mean width of blade relates to the actual blade—normally that part lying beyond radius 0.2 r approximately. The two values of the face areas employed are approximately 0.06 D^2 and 0.08 D^2. The numbers F_1 and F_2 are employed to designate respectively the straight or curved forms.

In Figs. 12 and 13 are given the results of these blades used as propellers, in Fig. 14, the results for these blades as windmills with negative thrust.

It will first be noted that these curves correspond very closely with the general trend of results at the N. P. L. The maximum negative thrust coefficient does not occur when the propeller does not rotate. As the V/nD increases, an asymptotic value of the thrust coefficient appears to be reached, while the maximum thrust coefficient occurs when the V/nD is not much larger than the V/nD for zero thrust.

The diagrams show that the narrow blades have less brake effect than the wide ones. They also indicate that the brake effect of the higher pitch ratio is less than that of the lower.

While in the National Advisory Committee's report, this is shown to be reasonable by virtue of the properties of a flat plate element, an explanation based on the treatment of a blade element as an aerofoil will appeal more to aeronautical engineers.

If we consider Fig. 2, it is at once evident that for a higher value of the pitch angle C, the negative angle of incidence will be less for the same value of V/nD, so that the lift and drag values will be less. At rest also with a higher pitch angle the angle of negative incidence will be smaller.

The Durand curves further indicate that the negative thrust coefficients attain quite an appreciable proportion of the positive thrust coefficients.

TABLE III. RESULTS OF TESTS ON A FOUR BLADED PROPELLER

Translation Speed, ft. per min	Rotational Speed, R. P. M.	V/nD	Thrust Co-efficient T_c	Torque Co-efficient Q_c	Efficiency e
1800	845	1.328	0.066	−0.0047	66
	882	1.020	0.000	+0.0018	0.0
	988	.918	0.040	0.0078	78.4
	1165	.772	0.115	0.0161	60.5
	1403	.648	0.256	0.0317	75.6
	1660	.555	0.394	0.0488	67.4
	1854	.460	0.548	0.0712	60.4
	2187	.411	0.778	0.0923	55.9
2200	100	11.60	−0.088	−0.0078	7.3
	608	1.744	−0.058	−0.0070	48.3
	658	1.188	−0.027	−0.0024	48
	1078	1.02	0.000	+0.0018	0.0
	1186	.952	0.027	0.0058	73.1
	1318	.856	0.079	0.0180	81.2
	1554	.717	0.158	0.0327	78.2
	1787	.617	0.208	0.0350	78.7
	2050	.587	0.394	0.0403	67.3
	2274	.468	0.521	0.0640	62.7
2600	0	∞	−0.045	−0.0058	0
	126	10.3	−0.058	−0.0070	8.1
	250	5.2	−0.057	−0.0078	16.0
	575	2.27	−0.057	−0.0078	37.8
	740	1.707	−0.052	−0.0070	47.0
	1048	1.244	−0.035	−0.0044	58.5
	1189	1.097	−0.019	−0.0011	38.1
	1274	1.020	0.006	+0.0014	0.0
	1360	.972	0.019	0.0044	67.2
	1471	.883	0.080	0.0096	81.0
	1674	.777	0.113	0.0174	80.0
	1906	.681	0.180	0.0285	77.2
	2157	.602	0.281	0.0378	72.1
	2368	.548	0.372	0.0480	67.0

Static Test $T_c = 0.1803$
$Q_c = 0.01797$

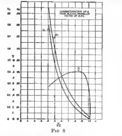


FIG. 8

Braking Effect of Propellers on a Landing Run

It has been shown in the paper previously mentioned ("Landing Run and Get-Away for Standard Airplanes") that in the case of the Curtiss R-4-L, equipped with a 400 hp. Liberty motor, and swinging a 9 ft. No. 5 propeller of Dr. W. F. Durand's Report, No. 14, at a landing speed of 52

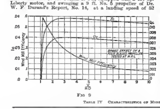


FIG. 9

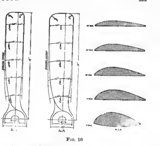


FIG. 10

m.p.h. the negative thrust would be 55.5 lb. at an r.p.m. of 270.

With propeller No. 10 of Dr. Durand's series, under approximately the same conditions, a negative thrust of 100 lb. is possible.

It is quite possible therefore that with a suitable propeller pilots might be able to shorten the landing run quite appreciably after some experiments in coordination.

Braking Effect of a Propeller on a Glide

If the four-bladed R. A. F. propeller, for which test results have been given, is again taken to have a diameter of 8 ft., then with the engine at rest the negative thrust on a glide of 100 m.p.h. would be 145 lb., the thrust coefficient with propeller at rest being 0.045. This for a machine of a size employing this propeller would be quite appreciable, and be sufficient to vitiate results of any gliding test for the determination of the resistance of a full sized machine.

Braking Effect of a Propeller in a Twin Engine Machine

The braking effect of a propeller in a twin-engine machine is important from the point of view of actual operation, and from the point of view of tests in flight.

If the mechanical losses torque is so large that with complete throttling the engine is at rest, the maximum braking effect is not attained. If the mechanical losses are small enough so that the wind mill action of the propeller is sufficient to turn the engine against them, the maximum braking action may well be attained with the engine completely throttled. But it may also occur that the windmill torque of the propeller is too small to turn the engine over. Or it may have to be supplemented by the torque of the engine itself,

TABLE IV. CHARACTERISTICS OF MODEL PROPELLERS. (see figs. 6 and 6a.)

No.	Diameter Inches	Nominal Pitch Inches	Mean Blade Width Inches	Form, Section Symbol	Radius of Section Inches	EG Inches	AB Inches	AE Inches	A & SD Inches	EH Inches	RS Inches	O
1	36	32.4	0.18 r	$F_1A_1S_1$	4	1.10	2.45	.60	.08	.70	0.18	79
					7	1.01	2.70	.60	.05	.60	0	60
2	36	25.2	0.18 r	$F_1A_1S_1$	10	.84	2.70	.60	.06	.60	0	50
					13	.60	2.70	.60	.05	.40	0	31
5	36	18.0	0.18 r	$F_1A_1S_1$	16	.45	0.70	.60	.35	.36	0	33
6	36	32.4	0.20 r	$F_2A_2S_1$	4	1.10	3.27	1.20	.05	.70	0.20	78
					7	1.01	3.60	1.20	.05	.60	0	69
9	36	25.2	0.20 r	$F_2A_2S_1$	10	.84	3.60	1.20	.03	.50	0	60
					13	.68	3.60	1.20	.08	.40	0	31
10	36	18.0	0.20 r	$F_2A_2S_1$	16	.48	3.60	1.20	.05	.30	0	53

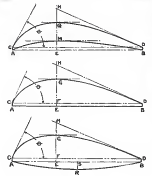


Fig. 11

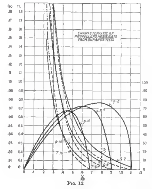


Fig. 12

and the maximum braking effect attained when the engine is working. Each case requires a careful analysis of engine and propeller conditions.

As a concrete example we may take the twin-engine Glenn Martin bomber.

If this machine were travelling on one motor at a speed of 75 m.p.h., carrying a Durand Propeller No. 5 of 9 ft. 6 in. diameter, then the thrust curve of the propeller would be as shown in Fig. 14. At a V/nd of 1.8, corresponding to 382 r.p.m., the negative thrust is 115 lb., which would be quite an appreciable drag on the machine, particularly as this would increase the rudder action required, and the consequent inefficiency with the same propeller at rest the negative thrust would only be 87.5 lb. At a V/nD of 1.0 the negative thrust is zero. In this case the engine would be turning over 690 r.p.m. This would be far too high for wind mill action to carry the propeller round. This rough analysis indicates that in testing a twin-engine machine for flight with one motor, careful value should be made for the conditions of the test, to allow one motor to turn over would render the conditions of a single engine test unduly easy, since the negative thrust of the dead motor might be completely nullified. It further indicates that a twin-engine machine is less likely to be able to sustain flight on one motor, than calculations neglecting negative thrust would show.

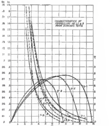


Fig. 13

A decompressing device might be of considerable service for a twin-engine machine, since it would enable the propeller to revolve the engine much more rapidly and enable it to reach that value of V/nd where thrust coefficient is zero.

Starting an Engine on a Glide by a Windmill Action of the Propeller

Experiments on the friction horsepower of a 180 hp. Hispano-Suiza at low r.p.m. have recently been carried out at the Bureau of Standards and the results are plotted in Fig. 14. It may be noted that a low r.p.m. the friction losses are almost the same for both throttles open and closed.

Adapting the 7 ft. 9 in. N. P. L. 4-bladed propeller, as previously described, to this engine and considering the airplane diving at a speed of 100 m.p.h. with motor not firing, if the propeller be turning at 294 or 470 r.p.m. the windmill torque would be 170 lb. ft. in both cases and the windmill power would be 9.7 and 15.0 hp. respectively. This is more in either case than the friction horse-power of the engine. Therefore, if the motor stops firing after the machine attains the speed of 100 m.p.h., the propeller will slow down till to a certain r.p.m. at which the windmill power of the propeller

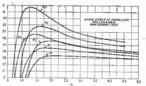


Fig. 14

is equal to the friction power of the engine. The r.p.m. in this case would be 470. Should this rate of turning be sufficient to produce an efficient spark for the magneto, it would be possible to start the engine by the windmill action of the propeller on such a glide.

It would be of interest to consider the propeller completely at rest and to investigate whether the windmill torque was sufficient to turn over the engine. The lack of data on the static friction horse power of the engine, however, makes this investigation impossible at the present moment.

REFERENCES

Experimental Research on Air Propellers, 1 and 2. Dr. W. F. Durand, National Advisory Committee on Aeronautics.

Summary of Present Knowledge with Regard to Airscrews by R. McK. Wood. British Advisory Committee for Aeronautics, R & M 594.

Introduction to Propeller Theory, by Alexander Klemin, AVIATION AND AERONAUTICAL ENGINEERING, March 15, 1920.

Tests on a Four Bladed Propeller for Thurst and Efficiency, the experiments being extended to negative values of the thrust to determine the resistance during gliding flights. By A. Fage, and F. H. Bramwell, British Advisory Committee for Aeronautics R & M 123.

Experiments on an Aerofoil (R. A. F. 6) to find the Effect on the Forces and Moments of Varying the Angle of Incidence from 0° to 360°. British Advisory Committee for Aeronautics R & M 152.

Landing Run and Get-Away for Standard Type Airplanes, by Alexander Klemin, S. A. E. Journal, April 1920.

A Study of Airplane Engine Tests, by Victor R. Gage, National Advisory Committee for Aeronautics, Report 46.

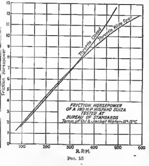


Fig. 15

Gun-Airplanes Against Tanks

A number of very interesting tests were recently conducted at McCook Field to determine the relative value of bombs and the new 37 m.m. cannon when used to attack tanks at low altitudes.

The first flight was made by Lieut. H. R. Harris in a Martin Bomber on which a 37 m.m. cannon, firing a one pound shell was mounted on the nose. He flew over the target a number of times at an altitude of 100 feet traveling at the rate of 120 miles per hour while Lieut. O. G. Kelly operated the cannon. The first three shots fell a foot short, the remaining five were direct hits.

Then a DeH-4 was flown over the target, loaded with eight fragmentation bombs. The bombs were dropped singly to obtain the range and dropped about thirty feet wide of the target. On the next circle of the field the remaining six bombs were dropped in salvo. Two bombs made direct hits, and the remaining four passed over the target at a height of three or five feet striking less than thirty feet beyond the target.

If the target had been an actual tank all six bombs would have registered direct hits. The results are considered quite remarkable, as the entire test was carried out below 100 feet at which altitude ground speed has to be contended with, plus very accurate judgment in firing.

Armored Airplane for Ground Strafing

A new armored triplane and an observation plane, designed and built by the Engineering Division of the Air Service, have just been tested at McCook Field, Dayton, Ohio. The tests proved to be a great success.

The armored craft is the Le Pere triplane, equipped with two Liberty engines. Both engine and fuselage are completely armored. It carries eight machine guns and 37 m.m. cannon and performs and handles very well in the air. This plane is well equipped and protected for battles in the air at high altitudes or for ground strafing troops close to the earth.

The new observation plane U. S. XB1-A, with 300 hp. Hispano-Suiza engine, was flown by General Mitchell, who

The New Handley-Page Wing

With regard to the novel wing form discovered by the technical department of Handley Page, Ltd.—which is said to double the lifting power for the same linear dimensions—the following account from *The Aeroplane*, may shed some light on this remarkable discovery.

Our contemporary states that an Airco DH-9 fitted with a set of the new wings has been flown with apparent success, and says:

"As to the means by which these results were obtained, no definite information is to be had. It is, however, certain that Captain Wedgwood Benn was not accurate in stating, as he did in the House of Commons, that the high lift is due to a shutter which decreases the surface for lifting and increases it for high speeds.

"So far as one can gather, some idea of the system may be grasped by studying the theory of the Howard Wright double-camber wing of 1913 in conjunction with the high-lift Fokker wing used in the triplanes of 1917-18. It is possible that by a combination of these systems extremely high lift may be obtained for starting and landing, and that high speeds when once aloft may be achieved by building the wings with a disappearing bump. The means by which the bump is made to disappear would probably be subject matter for numerous patents."

Over-Cloud Flying and Commercial Aeronautics*

By Prof. Melville Jones

The problem I propose to consider tonight is that of long-distance flight when the country is covered with a practically continuous layer of clouds with low under surface and bad weather underneath—the kind of day in fact that we know, to our cost, predominates in this country in the winter months. The more pleasing kind of day that is cloudy, but on which the clouds are sufficiently broken to allow of one flying in between or over them without entirely losing touch with the ground, I class as fine and place it out of our consideration tonight.

To assist you in getting a grip of what might otherwise be rather a diffuse argument, I shall, at this point, give a condensation of the argument that I propose to try and develop tonight. I do not expect everyone to agree with this argument, I rather hope that some people won't and will give their views with vigor in the discussion to follow. I am definitely taking sides in the argument, the side that over-cloud flying will, if properly conducted, prove ultimately to be the best way of tackling the type of bad weather that I have just described. The most condensed form of my argument that I can devise is as follows:—

On cloudy days one can fly either beneath or above the clouds; in connection with each method there are difficulties and dangers, but these are of an entirely different type in the two cases. Peculiarities of each method may be summarized as follows:—

1. Under-cloud flying can be successfully performed commercially by individual effort, but will always be at a serious disadvantage compared with fine weather flying.

2. Over-cloud flying can *only* be engaged in *commercially* with the assistance of organization on a large scale, and with certain apparatus, additional to what is essential for fine weather, given these conditions, however, it is capable of development to such an extent that it is very little inferior to fine weather flying as a commercial proposition.

3. Individual effort, unless assisted by far seeing organization on a large scale, is liable, of necessity, to develop under-cloud commercial flying at the expense of the alternative method, although the latter is likely to achieve better results in the long run.

Difficulties of Flying Under Clouds

For the sake of clearness I have classified the objections to under-cloud flying as follows. These are not necessarily given in order of importance.

1. Strain to pilot.
2. Danger of collision.
3. Discomfort to passengers and pilots.
4. Loss of power to use favorable winds.
5. Annoyance to people on ground.
6. Danger in forced landings.

I will deal with these drawbacks in detail in order to develop the first part of my argument, i. e., that under-cloud flying in bad days, whilst being possible to determined individual effort, will always suffer from serious drawbacks in spite of any foreseeable developments in organization or science.

Pilot Strain. In my experience the strain of long continued under-cloud flying, when the clouds are low and the visibility bad, is very great. This is mainly due to the incessant watchfulness that is necessary to avoid losing the way, and to avoid collisions when the air is at all crowded. The strain is, however, accentuated by the almost continuous bumps that are usually encountered. The mere physical effort of counteracting these bumps for hours on end is quite fatiguing, to say nothing of the weariness, due to being shaken about, comparable with that produced by a long motor drive on very bad roads. The contrast between the mental and physical effort required under these conditions and when merely keeping a compass course above clouds in clear air, free from bumps, must be felt to be believed. This contrast will probably be accentuated in time by the use of gyro automatic course maintainers in the latter case.

Danger from Collisions. When the clouds are low, say below 2,000 ft., everyone flies as high as possible without losing sight of the ground, so that almost all aircraft will be confined, on these days, to a layer no more than 200 ft. thick. This greatly increases the chances of collision. Immediately under clouds, on bad days, the horizontal visibility is very low, and this still further increases the danger of collision. I believe that this difficulty will become very serious when the air becomes crowded. At present it is not serious except in the neighborhood of aerodromes. When flying over clouds in clear air, collision dangers are practically non-existent. The problem of avoiding collision in clouds will be dealt with later.

Discomfort of Passengers and Pilot. The contrast between the pleasure of flying over clouds and the discomfort of flying under clouds in bad weather is very great, and must be felt to be believed. It is difficult to convey any idea of the feeling of exhilaration produced by the absolute isolation, the clear blue sky above and the brilliant white cloud forms beneath. The only way to appreciate the feeling is to get above the clouds either on a mountain or in an airplane. Flying under clouds on a bad day, on the other hand, is like a channel crossing in rough weather. Seriously, I think that this is a very important commercial consideration from the point of view of passenger-carrying.

Loss of Choice of Height. The economy of commercial flying will depend largely upon the intelligent use of favoring air currents at particular heights. In fine weather I imagine this will be the determining factor of height. On bad days, pilots who can choose between flying under or over clouds, with perhaps considerable choice of height in the latter case, will have a very great pull over pilots who are forced to keep low; it is quite an ordinary occurrence for the wind at a great height to be exactly the opposite to the wind near the ground.

Annoyance to People on the Ground. This does not at present sound a very serious matter, but I venture to suggest that people living on a heavily used route along which the large multi-engined machines pass close overhead during most of the winter, will get restive, to say the least of it. Whether their restiveness will do them any good, or the aircraft any harm, is another matter.

Danger in Forced Landings. Forced landings in bad weather will be dangerous either from above or below clouds. One hopes they will get fewer and fewer as time goes on; if they don't, bad weather flying of any kind will be impracticable; they will, however, always have to be reckoned with to some extent. The worst case when flying low is when the engine fails whilst flying down wind, a rapid turn then has to be made, with consequent loss of precious height and choice of landing ground. One has, however, the advantage when flying below clouds that one has a fairly clear idea of the lay of the land at the moment the engine fails.

In forced landings from over clouds one has not the latter advantage, but one has two balancing advantages:—

1. There is time to consider possible trivial causes of failure and to right them, thus avoiding the forced landing altogether in a large number of cases. There is no time for this from a low height as the attention from the start must be focussed on the actual landing.

2. If the pilot possesses a knowledge of the wind direction near the ground, he should arrive through the clouds already flying up wind and with a mind alert to the danger.

The difficulty of the clouds extending to the ground, when one is above clouds, will be discussed later; when below clouds one can see this difficulty coming and avoid it.

The arguments just discussed form a rough survey, so far as I myself am able to analyze them, of the reasons why I feel that under-cloud flying on bad days, when the clouds are low, is not going to be a very satisfactory operation, particularly when carried out over crowded land areas, such as the British Isles. I have tried to bring out the advantages of over-cloud flying in direct contrast to each drawback of under-cloud flying, apart from the dangers and difficulties of over-

* Paper read before the Royal Aeronautical Society

cloud flying that I now propose to discuss, these advantages are such that I imagine that there would be no hesitation in deciding for over-cloud flying in bad weather, whenever possible.

Difficulties of Over-Cloud Flying

We will turn now to a discussion of the difficulties and dangers of over-cloud flying and attempt to develop my second argument, namely, that over-cloud flying can *only* be indulged in *commercially* with the assistance of a large organization and with special apparatus, but that, given these, it shows possibilities of development to such a pitch that it will be little inferior for commercial purposes to fine weather flying.

As in the former case, I will begin by roughly classifying the difficulties and dangers and then deal with each in detail. My classification is as follows:—

1. Difficulty of actual in-cloud flying.
2. Danger that the clouds may come to the ground whilst airplane is in or above them.
3. Difficulty of navigation.
4. Difficulty of aerodrome finding at end of flight.
5. Danger of collision in clouds.
6. Possibility of having to reach great heights to clear clouds.
7. Danger from storm clouds.

Flying in Clouds

The essence of the difficulty of flying in clouds lies in the fact that it is impossible to distinguish between the effects of gravity and of acceleration. For instance, a man in a lift that is accelerating downwards imagines that his weight has become reduced, and but for the fact that his other senses, such as sight and hearing, may tell him he is in a lift and therefore probably descending or ascending, he has no way of telling that his weight has not been reduced by the earth getting tired of pulling at him. In other words, an acceleration, or rate of generation of motion, cannot be distinguished from a change of weight.

Now consider a man in an airplane that is turning in a curve; most of you know that under these conditions his acceleration, or rate of change of motion, will be at right angles to his momentary direction of motion.

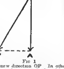


Fig 1

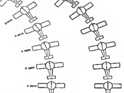
Suppose O (Fig 1) is an airplane travelling into the paper, but turning to the right. Its acceleration is to the right along OC, and the pilot cannot distinguish this fact from what would occur if there were an additional earth out to the left attracting him to the left along OB.

The combination of this imaginary earth pulling along OA, the true vertical, produces the effect of a somewhat stronger earth than the real one pulling in the new direction OP. In other words, the pilot has an apparently new vertical, and has no internal means of knowing that this is not the true vertical except that he will feel a little heavier than usual, by just as much as OP is longer than OA.

Now it is easy to see that OP does not grow much bigger than OA until the angle POA is quite large, and a man does not seem, in practice, to be at all sensitive to small changes in weight, especially when the change is gradual. Hence, in practice there is no means of telling that the apparent vertical is not the true one until the angle between the true and false vertical is very large, even then, only the fact that the vertical is wrong is appreciated, not the direction in which the error lies. Any experienced pilot will realize this point at once from the fact that he can sit quite squarely in his machine with his cross bubble in the center on quite a steep bank, provided that the bank is correct for the turn.

The fact we have discussed introduces no difficulties to a trained pilot flying in the open, because he preserves his idea of the vertical by looking at the horizon; all pilots do this whether they know it or not. Once let the pilot enter a cloud, however, where he cannot see the horizon, and the fact just considered becomes of vital importance.

Let us follow the case of a pilot, unequipped for cloud flying, who enters a cloud for the first time, and let us imagine that he has no compass. He goes in quite straight and level and, if he is a fairly experienced pilot, keeps his speed moderately constant for some time, using his elevator, either by feel or with the help of his speed indicator. The inside of a cloud however is generally very bumpy, and in trying to



SHORT PERIOD COMPASS ON SLOW TURN FROM NORTH, 180° TURN IN 40 SECS AT ABOUT 70 M.P.H. CORRESPONDING BANK ABOUT 14°

SPECIAL LONG PERIOD COMPASS UNDER SIMILAR CONDITIONS.

Fig 2

correct these bumps he gets upon a bank and starts a turn. His instinctive correction then only results in making the bank and the turn suit each other, *not* in levelling him up again, and for some time, greater or less according to chance, he goes on in blissful ignorance that he is steadily getting on to a steeper and steeper bank and a sharper and sharper turn. All this time he would take his oath that he is perfectly level, and if, during this stage, which may last a minute or two (this seems a long time in a cloud), he comes out of the cloud again, he probably rights himself and goes on with the mistaken belief, that may subsequently cost him his life, that he can fly in clouds.

Let use suppose, however, that the cloud is a large one, his first indication that something is wrong is, as a rule, either an increase or decrease of speed that is not counteracted by the accustomed movements of the controls. A period of wild suspense and utter bewilderment now follows, during which the pilot makes violent efforts to recover control, but without success. The next thing that he realizes, if he realizes anything at all, is that he is either on his back or spinning, and the next thing he knows is that he is out of the clouds with the earth standing up at a ridiculous angle and spinning round like a drunken dinner plate. Happy is he that has plenty of air room under these circumstances.

What has happened is obvious to anyone but the unfortunate crew of the airplane. The bank has increased without the pilot's suspecting it until a new system of control is required to maintain steady conditions; the pilot having no knowledge of this instinctively acts as he would were he level, with the result, chaos!

I have not overdrawn this gruesome picture, I have been through it myself as an observant passenger, and have talked to many others who have been through it. Many a good pilot has had his last living view of the earth in this wildly gyrating form.

SHORT PERIOD COMPASS. SLOW TURN FROM SOUTH

180° TURN IN ABOUT 40 SECS

APPROXIMATE BANK 14°

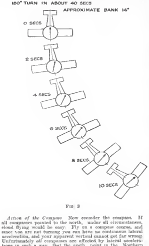


Fig 3

Action of the Compass Now consider the compass. If all compasses pointed to the north, under all circumstances, cloud flying would be easy. Fly on a compass course, and since you are not turning you can have no continuous lateral acceleration, and your apparent vertical cannot get far wrong. Unfortunately *all* compasses are affected by lateral accelerations in such a way that the north point in the Northern Hemisphere swings towards the direction of acceleration, i. e., to the inside of the curve when turning. I shall not go into the proof of this, which depends on the fact that the earth's field is not horizontal but sloping down to the north; it will suffice to say that, so far, no practicable way has been discovered of overcoming this difficulty, nor is one likely, in my opinion, to be forthcoming.

When flying south this peculiarity of the compass is an advantage rather than a disadvantage, but when flying north the reverse is the case. The diagrams, Figs. 2 and 3, should make this point clear. These are produced from actual experimental figures.

Flying north it is clear from Fig 2 that the compass is of very little help as a means of flying straight, in some cases it is a distinct hindrance. The pilot following his compass is confirmed in his belief that he is flying straight when actually he is turning rapidly, in some cases he is actually encouraged to increase his turn. It must also be remembered that the accelerations produced by bumps, which almost always occur in clouds, disturb the compass very much, so that, even when flying south, control may be lost by an injudicious attempt to follow the perturbations produced in this way.

Once the violent accelerations attendant on actual loss of control have started, the gyrations of the compass, as seen from the airplane, become something terrible, in a word, it appears to go quite mad, spinning and stopping again in a perfectly diabolical manner, so that the poor pilot who meets these phenomena for the first time is only confirmed in his belief that the laws of nature, as he is accustomed to them, are temporarily suspended. Figs. 4 and 5, taken from life, show a mild case of what can occur on a moderately sharp turn.

It must not be supposed from the foregoing remarks that it is impossible to fly in clouds with the aid of a compass and the ordinary instruments only, on the contrary, we even managed during the war to train several formations of comparatively inexperienced pilots to fly so well in clouds that they could actually pass through clouds 6,000 ft. thick, in formation, and this without the use of special instruments, the operation, however, was recognized to involve war risk. Under these conditions the long period compass, the action of which is illustrated in Figs. 2, 4 and 5, was found to be an absolute necessity.

Possibly I have said enough to indicate that cloud flying without special instruments, although possible with training, involves too great a risk for commercial purposes, besides being in practice confined to flights not lying within 45 deg. of north.

For war purposes the importance of cloud flying is obvious, because of the cover provided by the cloud, vigorous efforts were therefore made to devise instruments to make cloud flying easier, with the result that there are now no less than three types of cloud flying instruments in existence, working on entirely different principles; any one of these makes cloud flying comparatively simple.

LONG PERIOD COMPASS QUICK TURN FROM NORTH

180° TURN IN 15 SECS AT ABOUT 70 M P H.

CORRESPONDING BANK ABOUT 35°

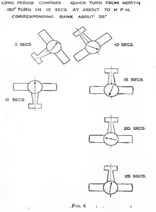


Fig. 4

These three types can be grouped under the following heads.—

The Static Head Turn Indicator.
The Spinning Top
The Gyro Turn Indicator.

Static Head Turn Indicator. The Static Head Turn Indicator, due primarily to Sir Horace Darwin, has already been described in this Society. I will describe it again briefly for the benefit of those who were not then present.

A pressure gauge P, Fig 6, is connected by tubes to two static heads or devices for measuring true pressure S_1S_2; these are situated on the wing tips. The gauge reads a small difference of pressure when the airplane is turning owing to the centrifugal force in the tubes T_1 and T_2.

So far the device might be thought to be merely equivalent to an elaborate cross level, whilst the airplane is level it reads the same quantity as the ordinary bubble cross level.

When the airplane banks, however, the tendency of the air to flow down the tubes T_1T_2 is neutralized by the barometric pressure difference between the points S_1S_2, due to their being at different heights. The centrifugal force on the air in the tube is thus still free to make itself felt so that the instrument reads lateral accelerations independently, or nearly independenly, of bank. In this, of course, it differs from the bubble cross level.

In any *steady* flight lateral accelerations imply a rate of turn, and hence the instrument, although in reality a thwartships acceleration indicator, may be considered to be a turn indicator.

In practice this instrument works very well, and its presence on an airplane makes cloud flying safe, since by its use it is always possible to tell which way one is turning or trols. It has, however, three serious defects for use as the sole

SHORT PERIOD COMPASS. QUICK TURN FROM NORTH

180° TURN IN 15 SECS AT ABOUT 70 M P.H

CORRESPONDING BANK ABOUT 35°

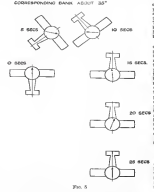


Fig. 5

spinning and to apply the necessary corrections on the conextra instrument for cloud flying on a commercial machine. These defects are as follows.—

1 The action of the instrument depends on the measurement of very small differences of pressure in the presence of possibilities in the way of violent pressure disturbances due to the rapid air flow past the static heads. It is thus easily put out of order. Kinks in the tube, etc., are sufficient to disturb its reading seriously.

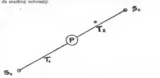


Fig 6

2 As at present constructed there is an excessive "lag" between the starting of the turn and its registration.

3. As at present constructed it is very much influenced by side slip. This is not a fundamental difficulty, but is thought to be due to the unsymmetrical influence of the airplane itself on the neighboring air, when side slipping.

4. It is possible, though rare, for the static heads to freeze up solid and put to instrument out of action. When this happens in a cloud the speed indicator will also be out of action and disaster would probably follow.

Defects 1 and 4 relate to reliability, an important matter in commercial work. Defects 2 and 3 make it practically impossible to fly a good straight course, using the turn indicator as the primary instrument, the compass has to be used for this purpose and the turn indicator as an occasional corrector. The defects of a compass as an instrument for flying straight have already been considered. In spite of these defects the Static Head Turn Indicator produced an immense simplification in the art of cloud flying.

Spinning Top The Spinning Top cloud flying device consists of a top spinning about a point near its center of gravity and carrying some indication to show the direction in which the axis is pointing. The usual method of doing this is to prolong the axis upwards by a light rod with a white ball top and to cover the whole with a hemispherical glass bowl provided with reference marks. The axis of this top tries to remain vertical despite tilts of the airplane, or accelerations, it does not quite achieve this object, but for small and not too continuous acceleration it makes a passably good attempt. The instrument is used in clouds as follows.— The top is placed so that the pilot can look down on the hemispherical glass bowl which swings with the airplane. The top axis remains approximately vertical, and hence when the airplane tilts, it appears to the pilot to move in the bowl. If the pilot follows the apparent movement of the ball on the top axis with his stick, he makes the correct movements to restore his machine to a level position, this is easily verified. When the airplane is kept on an even keel, as explained above, turning is indicated on the cross bubble level and is therefore easily prevented by the use of the rudder.

This instrument has two great advantages that particularly fit it for use in light unstable airplanes. These are.—

1. Its indications are instantaneous.

2. It indicates fore and aft level as well as lateral level.

The latter is an important point in unstable or untrimmed airplanes, since, in the absence of the horizon, such an airplane is very difficult to control fore and aft, because variations of the speed indicator do not begin to show until the nose has been up and down for some little time. In stable aircraft, that can be trimmed fore and aft, this is a matter of minor importance only.

The chief defect of the instrument is that violent maneuvers upset it altogether and hence it is of no help in regaining control after control has once been lost. There were also, I believe, difficulties with the pivot, but probably these have been overcome by now. Apart from these defects the instrument undoubtedly makes cloud flying comparatively simple with very little previous training. Clearly it does not, by itself, provide the absolute safety required for commercial work, and it is ruled out for fighting airplanes by the fact that it cannot stand "stunts."

Gyro Turn Indicator. The Gyro Turn Indicator developed by the Royal Aircraft Establishment from a similar device by Professor Henderson for use in ships, provides, to my mind, the best instrument for all round use. This consists of a gyro wheel spun directly by the air flow past the airplane. The axis of spin is fore and aft, and the whole is able to precess about a thwartship axis. The precession is controlled by relatively strong springs and its deflection against these springs is magnified and read on a dial, the deflection being proportional to the rate of turning in space. The chief merits of this instrument are:—

1. Its extreme simplicity and coarseness of construction, owing to the forces involved being so large that no delicate parts are necessary. It is therefore very reliable.

2. No amount of stunting puts it off its good behavior so that it is available to regain control at any time after control has been lost.

3. It is almost instantaneous in action, registering even a small turn the moment it begins and before any appreciable turn has taken place. For this reason it can be used as the primary straight flying instrument and the compass returned to its proper sphere of duty, that of an instrument to tell one from time to time where one is going.

With this instrument cloud flying on a machine that is stable and trimable fore and aft should be perfectly simple and require no more training than is required to give the pilot confidence in his instruments. With it the compass is not required to register turns correctly on a north course, but it should be of good behavior in bad bumps.

Summarizing the situation with regard to the operation of flying through clouds, I think it is possible to state quite definitely that, whilst cloud flying without special instruments is a difficult and dangerous operation, unsuited to commercial work, yet there are three distinct and tried forms of apparatus that make it feasible, and one, at least of these, the Gyro Turn Indicator, whilst being simple, reliable and cheap, makes cloud flying practically as safe as open air flying, apart, of course, from the question of collision which we will consider later.

Danger of the Clouds Coming to Earth whilst the Airplane Is Above Them

We now turn from the actual passage through the cloud, which we have seen to be feasible, to the most serious difficulty of all, the danger that whilst above, or in the clouds, the clouds themselves may come down to the ground. If this occurs without the pilot being aware of it, disaster on trying to land is practically inevitable; until this danger is satisfactorily overcome, over-cloud flying, of the type we are considering, is emphatically not a commercial proposition.

So far as I can see there is only one counter for this danger, and that lies in the use of the wireless telephone together with an organization that keeps the pilot informed of the state of the air under the clouds during almost the whole flight. I do not myself think that any means of communication short of direct speech on the telephone will be adequate for this purpose, on account of the complicated ideas that may have to be conveyed. It may, for instance, be necessary to tell the pilot that he cannot land at Hendon, but that at Croydon aerodrome the air is clear enough to get down; or again, that London is totally mist-covered and a descent should be made at Lympne or some other aerodrome short of London.

The organization that I should imagine for this purpose would consist of a train of small wireless stations along the route, at such distances, that one at least would be in communication by wireless telephone with the airplane during the whole flight. These stations would be linked by wire with the aerodromes along the route and with the Meteorological Office. One might hazard a guess at 100 mile intervals, with perhaps intermediate observation huts at shorter intervals, the latter connected with the main wire but not equipped with wireless. These intermediate stations would be manned on cloudy days only and would then report to the main stations when any dangerous lowering of the clouds in their area occurred.

With such a train of stations it should at least be possible to ensure that nothing short of complete engine failure should necessitate landing in fog. This would be a great step forward, because, in any case, commercial aeronautics is going to depend on forced landings being reduced to a negligible quantity. The forced landing due to a defective engine, when it does occur, presents, however, a serious difficulty on account of the fact that, although the ground at the wireless stations may be clear, the ground at the position of the forced landings may not be clear. It is mainly for this reason that the intermediate observation huts might be required; it might, by their use, be possible to keep the pilots informed of any districts on their routes that were extensively covered, so that if their engines failed they could use their height to get away from the danger areas. It must be remembered that the airplane, when over clouds, will generally be above 10,000 ft. and hence will have a circular area of about 12 miles radius from which to choose a landing ground; probably days on which the fog patches are more than 24 miles across will be considered unflyable in any case. The problem of how the pilot is to know where he is when the engine fails is dealt with later.

Difficulty of Navigation

Navigation over clouds can conceivably be carried out by one of several methods. These methods might be grouped under the following heads:—

1. Dead reckoning.
2. Observation of heavenly bodies.
3. By direct observation of fixed balloons or Archie bursts.
4. By the help of wireless.

Dead reckoning has been shown to give results that with great care can generally be relied upon to within about 10 miles in a hundred. But until meteorology has made very great strides, I do not think that one will be able to *rely* for commercial purposes on unassisted dead reckoning over distances greater than about 100 miles; one has to be so very reliable for commercial success. Dead reckoning for some distance will always be a part of any system of navigation out of sight of land, but alone it is not adequate for the purpose under consideration.

Observation of heavenly bodies looks very promising in connection with very long voyages, particularly over sea or over unmapped country, but it is rather too cumbersome a method for use in relatively short flights of 200 to 500 miles, such as I have in mind in this paper. At the best this method of obtaining one's position does not look likely to give results much better than from within 5 to 10 miles; this accuracy is amply good enough for general purposes, say when crossing the Atlantic, but it is not very much help when the aerodrome has finally to be found in thick weather under clouds.

The use of observation points such as balloons or archies have the great disadvantage that in the former case there is a horrible wire passing up through the clouds, and in the latter case there is a hard and heavy shell to be got up through the cloud without hitting anything and to be brought down to earth again without damaging life or property.

The remaining method is by wireless. There are really four separate ways for using wireless:—

1. With large central stations, not necessarily on the route, receiving signals directionally from the aircraft and themselves working out its position and transmitting back to the aircraft.

2. With large beacon stations whose messages are received directionally on the airplane, the position being worked out on board.

3. With small beacon stations on the route whose signals are received directionally by the airplane with a fixed apparatus that allows the pilot to fly straight on the beacon.

4. With small direction receiving stations on the route that receive the airplane signals directionally and instruct the airplane accordingly.

Each system will probably have its special use, but for the purpose in hand only the last is, in my opinion, likely to yield good results.

An objection to 1 lies in the large size of the transmitter required on the airplane.

An objection to 2 is the special knowledge and apparatus required in the crew.

The objections to 3 are not so serious, and it might be a good competitor with 4, but for the fact that we have already come to the conclusion, on other grounds, that the airplane must be equipped with a wireless telephone set.

If, as I have tried to show, the wireless telephone in communication with a series of stations on the route, is a necessity for reasons of safety, then it seems to me that the following system of navigation coming under the fourth head possesses the most general advantages.

Imagine a much-frequented trade route, say from London to Paris, or London to Scotland or Ireland, and suppose that at the termini and at distances of say 100 miles there were stations equipped with wireless telephones and directional receiving sets; suppose also that the aircraft are equipped only with the wireless telephone transmitter and receiver. The course of a flight might be as follows:—

The aircraft starts from London with the best available information as to wind above clouds and state of the air below clouds along the route. The pilot immediately passes up through the clouds on the best course he can lay to get him to the first wireless station, say Folkstone. Let us imagine that his dead reckoning would have brought him within 15 miles to the west of Folkestone, although of course, he does not know this. When about twenty miles or more short of Folkestone, by his calculations, he calls up on his 'phone and asks for his bearings. Two alternative procedures are now possible. In the first the operator at Folkestone gives the bearing to the pilot from his station, and the pilot flies on the reverse of his bearing and ultimately, with a few corrections from the ground operator, arrives over the operator and is informed of this fact; the operator can tell this moment approximately by the fact that signals become indeterminate, or perhaps by the use of a direction finder with vertical motion. In the second procedure the pilot holds his course, and the ground operator estimates his shortest distance from his station by the maximum rate of traverse of his signals and a rough knowledge of his ground speed. In either case the pilot, without descending through the clouds, gets his position fairly accurately every hundred miles or so and carries on in between by means of dead reckoning. He is also of course kept informed, by the intermediate and terminal stations, of any serious meteorological change or impending change, either in wind above clouds or in the conditions below the clouds along the route.

Taking into consideration the argument that the telephone on the airplane is a practical necessity for over-cloud flying, it seems to me that some such method as that outlined above will provide the best means of navigation on much frequented routes, principally because it calls for a minimum of apparatus and technical skill in the pilot. All he requires is the ability to use a wireless telephone set and to lay a course for a short flight by dead reckoning. The directional wireless set is in the hands of a specialist, to whom wireless and not flying is the primary fact of life, and who is sitting in comfort in an office on the ground.

The meteorological problem of obtaining the wind above the clouds, with sufficient accuracy for the intermediate dead reckoning, introduces a difficulty, but not an impossibility; probably the most satisfactory method of obtaining the necessary data would be to use self-recording apparatus elevated by kite balloons situated permanently in areas prohibited for flying. There are other methods of obtaining this data, such as the observation by airplanes, of A.A. fire above the clouds, or again by the use of sound ranging on explosive signals carried by small free balloons. To all these methods there are objections, but it must be remembered that the high altitude winds do not vary rapidly with space, and hence it is possible to put the wind finding stations in unfrequented spots at considerable distances from the actual routes.

No doubt the actual observation at the control stations of the prevalent errors on any particular day would greatly assist in keeping the official wind at any height in agreement with the true facts. It might even be possible to develop some method of obtaining the wind in the first place by an observation of error in a very carefully flown course by a special airplane.

Minor Difficulties of Over-Cloud Flying

Difficulty of Locating the Aerodrome at the End of the Flight. Anyone who has tried it will realize how difficult it is to locate one's position when plumped down out of the clouds at an unknown spot on a day of low visibility. To locate oneself with reasonable rapidity under these conditions requires a very intimate knowledge of the details of the country. For this reason it would be a very great drawback to over-cloud flying if the final descent through the clouds were to occur at an indeterminate position that may possibly be several miles from the aerodrome.

With an aircraft equipped with the telephone, and with a traffic controller at the aerodrome equipped with directional wireless, this difficulty would practically disappear, for the traffic controller could actually lead the aircraft home even whilst passing through the cloud and could continue to lead it until within sight of the aerodrome.

Danger of Collision in Clouds. Except in the case of forced landings the airplane will only be in clouds when descending to, or rising from, the aerodrome. With heavy traffic continually passing up and down through the clouds over the aerodrome collisions are inevitable unless some central control is exercised. I believe that the only way in which this control can be managed is by the wireless telephone assisted by directional wireless receivers on the aerodrome. With this apparatus the aerodrome traffic controller could ensure that only a safe number of airplanes were in the clouds together and could have some idea of their relative positions. The in-coming airplanes might, for example, be kept on the down-wind side and the out-going on the up-wind side of the aerodrome, so as to avoid confusion. The traffic controller at a large aerodrome would hold a very responsible position; he would be somewhat like a mixture between a railway signalman and a harbor master.

Difficulty of Having to Fly Very High Occasionally to Clear Clouds. There are days when the clouds reach a height that it would be inconvenient to have to reach in an airplane, both on account of discomfort to passengers and pilot and of the great power reserve required to reach such a height. Again there will be days when the adverse winds at the height necessary to clear the clouds would be too strong to make the flight practicable.

On such days one must of course in any case fly below the clouds and put up with the discomfort; it is not contended that it will always be possible to fly above clouds, but only that it will often be possible to do so with advantage. On days of high wind, of course, airplanes passing in one direction would keep below clouds, whilst those going in the contrary direction would fly above them. Even flying below clouds, however, the directing stations would be of considerable value in bad weather.

Danger from Storm Clouds. It is possible that storm clouds might form whilst an airplane is actually above clouds and that the electrical distrubances might interrupt communication with the ground. If the danger is serious, then it would throw another burden on the meteorologist; he would have to predict these occurences in time to prevent serious harm. On such a state of affairs being predicted all airplanes would be brought down by wireless signal and made to finish their journey in discomfort beneath the clouds.

If I have succeeded in making myself clear I have indicated that in my opinion the development of over-cloud flying is probably essential to the full commercial use of aviation in this country, and that to develop over-cloud flying a good deal of organization on a large scale is necessary. This organization can be divided into three main groups:—

Meteorological, consisting of the continuous determination of wind above clouds and of the height of the top of the clouds, etc.

Constructional, in the laying down of wireless control stations at and between termini, on the main routes.

Instrumental and Training, in the provisions of the necessary instruments for cloud flying and dead reckoning, and in the training of pilots in their use.

With regard to meteorological organization, the first step is obviously to push on with the development of methods of recording the upper winds even when clouds are present, since

without this information dead reckoning over clouds is impossible. I believe this step is of great importance to the development of commercial flying—quite apart from over-cloud flying—because the knowledge of the wind forces and direction a various heights is obviously going to be of great economic importance, and it will be a serious handicap if this information can only be obtained after the clouds have cleared, having regard to the inevitable delay that must occur between the obtaining of the information and its reaching the aerodrome at which it is required How much more valuable would such information be if it were continuous both in clouded and clear weather so that immediate advantage could be taken by the pilots of a sudden clear up?

Of the various methods briefly indicated in the body of this paper I incline to the kite balloon with recording instruments, for by this method continuous records of the conditions at any desired number of heights can be obtained with no delay whatever The necessary instruments have already, I believe, been brought to a fairly advanced stage at the R A E

The organization of the control stations suggested is of course a large undertaking Ultimately I see in imagination a state in which the British Isles might be dotted over with such stations, exactly as at present the coasts are dotted with lighthouses. If this vision were ever realized there would be no difficulty at all in arriving on long flights from great distances, say by airship from America, and finding the earth covered by cloud One would be certain to pick up some station, obtain position and a general report on the weather conditions below clouds, and be passed on from station to station until the terminus was reached

With regard to the question of instruments and training of pilots, the instruments have passed the scientific development stage as far as flying in clouds is concerned and now only require general application

The training of pilots amounts to little more than teaching them to use and believe in their instruments Flying in cloud is a purely instrumental operation and some experience is generally needed to convince a good open air pilot of this fact As already stated we succeeded at Orfordness in training formations of pilots of only moderate experience to fly through clouds in formation, even without the turn indicators, if this was possible there should be little difficulty in training pilots to climb through clouds without embarrassment of a formation of other machines in the neighborhood and with the help of the gyro turn indicators

N. A. C. A. Reports

Copies of these reports may be obtained upon request from the National Advisory Committee for Aeronautics, Washington, D C

Spark Plug Defects and Tests—Synopsis of Report No. 51, National Advisory Committee for Aeronautics

Part I of this report discusses the various causes of failure of spark plugs, viz.: (1) Fouling with carbon deposit causing short circuit, (2) fouling with oil deposit causing open circuit, (3) breaking of the insulator, (4) preignition, (5) conduction through the insulator, (6) electrical puncture of the insulator, (7) minor trouble, such as warping and breaking of electrodes, etc. Types (1) and (3) are most frequent The causes, indentification and possible remedies for each trouble are discussed in detail Part II gives the results of gas leakage measurements on several hundred plugs, and tabulates the result on a basis of design, material, etc The principal conclusion is that tightness is a matter of workmanship rather than design. Part III describes the methods worked out for testing spark plugs in the laboratory for (1) electrical conductivity when hot, (2) resistance to thermal cracking, (3) gas tightness, (4) resistance to mechanical shock, (5) dielectric strength, (6) engine test.

Experimental Research on Air Propellers, III—Synopsis of Report No. 64, National Advisory Committee for Aeronautics.

This report presents the results of a series of tests in continuation of those previously reported in Nos. 14 and 30.

The tests covered in the present report include the following characteristics

Four propellers of nominal pitch ratio 1.3, uniform pitch, straight face and with four combinations of form of blade and area.

Five propellers of nominal pitch ratios 0.5, 0.7, 0.9, 1.1, 1.3, all of uniform pitch, one area and blade form, and with the driving face made slightly convex by adding a crown of one-sixth the normal thickness of corresponding straight face sections.

Four propellers of nominal pitch ratio 0.7, uniform pitch one blade form and area and four locations of the maximum thickness ordinate of blade section.

Three propellers of nominal pitch ratio 0.7, uniform pitch, one blade form and area and with three degrees of the deformation of the leading edge through pushing forward by successive increments.

Twelve propellers distributed over the pitch ratios 0.5, 0.7, 0.9, 1.1, 1.3, all with one blade form and area, and with radially expanding pitch derived in each case on the assumption of a constant value of the angle of attack.

Several of the propellers of these series combine with those previously reported on to form more extended series with all characteristics constant except one and that one varying by regular steps, others are intended to show, for a typical combination of other characteristics, the influence of some one feature, as for example the distortion of the leading edge, or the location of the maximum thickness ordinate of blade section

The results, as in Reports Nos 14 and 30, are given in two forms (a) Curves showing actually observed spots for values of thrust and torque coefficients over a wide range of values of V/ND, with resultant efficiency curves.

(b) Eiffel Logarithmic diagrams giving the relation between power, air density, speed, diameter and revolutions.

The paper is accompanied by a brief description of a method of carrying on the tests, with a general discussion of the results with reference to the points most noticeably brought out by the various series formed either by the models of the present report alone, or formed by them in conjunction with those covered by the earlier reports.

The report is illustrated with 24 full page sheets of curves and 3 pages of cuts showing geometrical forms and characteristics of models employed.

Wind Tunnel Balances—Synopsis of Report No. 72. National Advisory Committee for Aeronautics.

This report is divided into four parts, the first of which is devoted to a detailed description, with numerous illustrations, of the balance designed for the wind tunnel at Langley Field. The second part of the report treats of the sensitivity of the N.P.L. type of balance, the means provided for adjusting sensitivity and the effect on sensitivity of the rolling and yawing moments and cross wind force which appear when the oscillations of the balance throw the plane of symmetry of the model out of line with the relative wind

Part III is given up to a discussion of the possible errors of the N.P.L. balance. Seventeen factors are listed, and the importance and the means of combatting each is discussed. Finally, in the fourth part there are brief descriptions of four other types of balance (Eiffel, St. Cyr, Curtiss 2 axis, and Wright). The precision of each of these types and their most striking advantages and drawbacks are briefly discussed.

The Aerodynamic Properties of Thick Aerofoils Suitable for Internal Bracing—Synopsis of Report No 75 National Advisory Committee for Aeronautics.

This report deals with the results of a series of tests conducted at the Massachusetts Institute of Technology wind tunnel, with a view to developing aerofoil sections thick enough to permit of internal bracing and the use of cantilever wings without any external bracing of the airplane wing truss. The sections tested were based on the Durand 13, and were varied in section form, in thickness along the span, and in chord along the span. Tapering both in thickness and in chord was found to be highly beneficial to efficiency, and some of the wings developed gave L/D ratios practically as high at angles corresponding to very high speeds of flight as the best of the wing sections for normal type, together with very much higher maximum lift coefficients. In particular, it was found that the substitution of a thick tapered wing for R.A.F. 6 on a 3600-pound fighting biplane with Liberty engine would increase the maximum speed by 18 miles per hour, due to the saving in parasite resistance by entire elimination of the interplane bracing


AVIATION
MECHANICS
A limited number of
AVIATION MECHANICS
are desired for the
COAST GUARD AVIATION STATION
Morehead City, N. C.
Apply by letter giving past experience to
Coast Guard Headquarters
Washington, D. C.
ONE YEAR ENLISTMENT

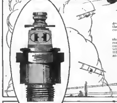
CLASSIFIED ADVERTISING

16 Cents a word, minimum charge $2.00, payable in advance. Address replies to box numbers, care AVIATION AND AERONAUTICAL ENGINEERING, 22 East 17th Street, New York.

FOR SALE—Double Acting Rudder, regulation for Aeronautics, patent 999959 license for 10 cents per horsepower, one straight move with one lever from and into any position. Box No. 121.

REQUIRED for position of responsibility and promise, energetic young man well acquainted in the airplane industry of good personality and business instincts. Box 122

INDEX TO ADVERTISERS




United States
Balloon · · ·
· · · Fabrics
A New Standard of Aircraft Service
NECESSITY guided our war-time efforts in the production of UNITED STATES BALLOON FABRICS. Since then, our policy of faith has been backed by a continued zeal in application. As a result, to-day we have standardized UNITED STATES BALLOON FABRICS to that degree of genuine service which is reflected in all the products of the world's oldest and largest rubber manufacturer.
Inquiries concerning UNITED STATES BALLOON FABRICS and any rubber goods used in aeronautics should be directed to the Aircraft Department, 1790 Broadway, New York City.
United States Rubber Company
UNITED STATES RUBBER COMPANY
US
RUBBER SYSTEM
AND ASSOCIATED COMPANIES